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Brief article

The development of a word-learning strategy

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Abstract

Two studies investigated young infants' use of the word-learning principle Mutual Exclusivity. In Experiment 1, a linear relationship between age and performance was discovered. Seventeen-month-old infants successfully used Mutual Exclusivity to map novel labels to novel objects in a preferential looking paradigm. That is, when presented a familiar and a novel object (e.g. car and phototube) and asked to "look at the dax", 17-month-olds increased looking to the *novel object* (i.e. phototube) above baseline preference. On these trials, 16-month-olds were at chance. And, 14-month-olds systematically increased looking to the *familiar object* (i.e. car) in response to hearing the novel label "dax". Experiment 2 established that this increase in looking to the car was due solely to hearing the novel label "dax". Several possible interpretations of the surprising form of failure at 14 months are discussed. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Word-learning; Mutual exclusivity; Disjunctive syllogism

1. Introduction

Word-learning is a problem of induction. For any new word, there are a myriad of possible meanings and possible referents. To help pare down this large hypothesis-space, children may use principles which constrain what a new word can refer to (Carey, 1978; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1992; Markman & Hutchinson, 1984; Mervis, 1987; but see Gathercole, 1989; Nelson, 1988). By looking at ever younger children, researchers hope to discover both the structure and the scope of these constraints. This article investigates the status of one such constraint, children's tendency to map novel labels to novel objects, in infants who are just beginning to learn words.

There have been multiple proposals as to the particular principle that guides children to map novel labels (i.e. labels with no known referent) to novel objects (i.e. objects for

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which the child does not know a name). To see how these principles may help constrain the possible referents of a new word consider one such principle, Mutual Exclusivity. Mutual Exclusivity (ME), simply stated, is the assumption that every object has just one name (Markman & Wachtel, 1988; Merriman & Bowman, 1989). Imagine that a child is presented with two toys. One is a toy car, and the child already knows the name “car”. The other has never been seen before. If the experimenter asks the child to “Hand me the car”, children as young as 16 months comply (Mervis & Bertrand, 1994). But, if the experimenter instead asks, “Hand me the dax”, how is the child to decide on the correct referent? Utilizing ME, the child may be driven to preferably map the novel label “dax” to the novel toy because the car already has a known label (i.e. “car”) and, according to ME, it cannot receive another.

Each of the different principles proposed to motivate the mapping of novel labels to novel objects (of which ME is one example) makes some commitment to an underlying computational structure. ME motivates the mapping of novel labels to novel objects via the rejection of objects that already have a known label (e.g. “car”) from consideration (Markman, 1990). The principles of Contrast (Clark, 1990, 1993) and a Pragmatic Account (Diesendruck & Markson, 2001; Tomasello & Barton, 1994) share this computational structure but offer a different motivation for the rejection of objects with known labels. Contrast proposes that children wish to avoid synonyms. Because known objects already have known labels (e.g. “car”), children will reject them as possible referents of a new word.[1] A Pragmatic Account offers that children reject known objects because of the social pragmatics against such a construal. That is, children might reason as follows: “If you had meant for me to give you the car you would have said ‘car’. But you said ‘dax’, so you must mean the novel toy.” (Diesendruck & Markson, 2001).

A fourth proposal is that children might simply “map novelty to novelty”. Proponents of the Novel-Name Nameless-Category principle (N3C) contend that children do not reject known objects from consideration (Mervis, Golinkoff, & Bertrand, 1994). Instead, children are simply positively motivated to map novel labels to novel objects (Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Mervis & Bertrand, 1994).

Whichever particular principle guides children’s behavior, two of the important open questions concerning all such word-learning constraints are: (1) do they help get word-learning off the ground by constraining children’s earliest word meanings? and (2) what are the computations that subserve constraints throughout word-learning, from early through mature use? Data from young infants who are just beginning to utilize a constraint may contribute to answering both of these questions.

I present a variation on the preferential looking paradigm (Allopenna, Magnuson, & Tanenhaus, 1998; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998; Hirsh-Pasek & Golinkoff, 1996) which will allow the status of the constraint on novel labels to be assessed at younger ages than previously reported. At approximately 17.5 months, children are able to successfully map novel labels to novel objects in a pointing game (Mervis & Bertrand, 1994). But developmental research has found that looking-time is often a more sensitive measure than reaching or pointing. Therefore, instead of asking young

[1] In this case, the principle of Contrast may also make use of the Whole Object Constraint (Markman, 1990) which motivates children to take a newly heard noun as a basic level object name.

babies to "hand me the dax", infants' change in looking to a novel object after hearing a novel label (e.g. "dax") is taken as a measure of success at mapping the novel label to the novel object.

2. Experiment 1

2.1. Method

2.1.1. Participants

The participants were 38 full-term infants (16 male) from predominantly English-speaking families (mean age 16 months, 0 days; range 14-7 to 17-25). Fifteen additional infants were tested but not included in the final sample due to: fussiness (2), side-bias (6), parental interference (4), and equipment failure (3). One subject was removed from the final analyses for performing more than two standard deviations below the mean, leaving 37 infants in the final sample.

2.1.2. Stimuli

Visual stimuli consisted of four computer-generated "3-D" objects (cup, ball, car, phototube) from the TarrLab Object DataBank (1996). Objects were presented as yoked pairs (cup–ball, car–phototube) on two computer screens with one object from the pair on each screen during a trial. Object color changed on each trial to help maintain infant interest. Auditory stimuli consisted of four labels ("cup", "ball", "car", "dax") matching each of the four objects (the phototube will be referred to as "dax" throughout). For each trial, a label was presented once after a carrier phrase and once in isolation (e.g. "Look at that [cup]. [Cup]!"). Auditory stimuli were recorded by a native English speaker. Three different carrier phrases were used randomly to help maintain infant interest ("Where is that ___?", "Find that ___.", "Look at that ___."). There was a single token of each carrier phrase and each label. This ensured that infants' responses would be driven by the label alone and not by any auditory differences between labeling acts.

2.1.3. Procedure

Before the study, parents completed a short inventory of their child's noun vocabulary. All children were reported familiar with the labels "cup", "ball", and "car" which were used as "known labels" throughout the study.

Infants were tested in a sound-attenuated room, seated on their care-giver's lap facing two computer monitors approximately 72 cm away. Care-givers were instructed to hold infants in the center of their laps, maintain forward gaze, and not cue infants verbally or physically. Violating these instructions led to the exclusion of the child from the final sample.

During each trial, two objects appeared simultaneously, one on each monitor. The objects remained static, in silence, for 3 s. During this time, infants' looking to each monitor was measured. This served as a within-trial measure of baseline image preference. After 3 s, a speech stimulus that correctly labeled only one of the objects was played (e.g. "Look at that [cup]. [Cup]!"). Following the onset of the first label (e.g. [cup]), infants' looking to each monitor was measured for 4 s. This served as a measure of infants' label comprehension. After this 4 s comprehension measure, the labeled object "danced" on the screen to music, and the distractor disappeared. This dancing created a pragmatically natural labeling context (Arriaga, Xu, & Carey, 1996), as if we were asking infants to look at an object and then showing them that something fun would happen involving it. This pragmatic naturalness was included to help maintain infant attention throughout the study. There is no evidence that this reinforcement drives children's performance (see Section 3).

Infants saw 24 trials broken down into two sets of 12 blocked trials, six known vs. known (cup–ball) trials followed by six known vs. novel (car–dax) trials. Each object was the labeled target on half of the trials and the distractor on the other half. Thus, each object (cup, ball, car, dax) was the labeled target on six trials overall. Order and side of presentation within each block were counterbalanced across subjects. Stimulus presentation was controlled by a Macintosh computer using PsyScope (1994) software.

Infants' looking was recorded by a video camera concealed between the two monitors. Looking was coded from video, frame-by-frame, at 30 frames per second using MacSHAPA software (Sanderson, 1994). Coders were blind as to the location (left–right) of the target. For each frame, coders assessed whether the infant was fixating the left monitor, the right monitor, or neither. The looking-time data were then normalized to the onset of the first spoken target label for each trial. This allowed trials to be collapsed and analyzed for success, measured as increased looking to the labeled target above baseline preference. Ten infants were coded independently by two coders and intercoder reliability, measured as the percentage of total frames per trial on which the coders agreed, ranged from 97 to 99%.

2.2. Results

Each infant's looking-times were collapsed by trial type (cup, ball, car, dax) creating a subject mean for each label. Percent-looking to the target object before label onset served as a measure of baseline image preference for that target. Percent-looking to the target after label onset, relative to baseline, served as a measure of label comprehension. Note that percent-looking represents time spent looking at the target object divided by the total time spent looking at either object. Therefore, 50% represents chance looking. Subtracting baseline preference-looking from comprehension-looking creates a difference score for each label, equivalent to the percentage increase or decrease in looking to the labeled target. Thus, success is seen as a positive difference score.

Difference scores were entered into a 4 (target) × 2 (sex) repeated-measures ANOVA to test for differences in performance between the four trial types (cup, ball, car, dax). There was a main effect of target ($F(3, 105) = 4.89$, $P < 0.01$) and no effect of sex. Planned comparison *t*-tests between targets showed that performance on the three Known Label trial types ("cup", "ball", "car") did not differ, and that performance on Novel Label trials ("dax") was different from that on Known Label trials. Therefore, subject means were combined for Known Label trials ("cup", "ball", "car"), and differences between Known Label trials and Novel Label trials ("dax") are analyzed below.

In order to test for an age-dependent change in performance, difference scores for

Known and Novel Label trials were entered into a linear regression with age as the independent, continuous, variable. As seen in Fig. 1, there was no trend for performance to increase or decrease with age for Known Label trials ($t(1, 35) = -0.17, P = 0.86$). That is, all ages successfully increased looking to the labeled targets (cup, ball, and car) equally. This was not the pattern observed on Novel Label trials ("dax"). Difference scores on Novel Label trials increased significantly as a function of age ($t(1, 35) = 2.29, P < 0.05$). As seen in Fig. 1, difference scores on Novel Label trials were mostly negative for younger children (14–15 months), then became highly variable (15.5–16.5 months), and were mostly positive for older children (16.5–18 months). For the purpose of further analyzing this pattern, the continuous variable of age was divided into three groups: "14-month-olds" ($N = 11$), mean 14 months, 19 days; range 14-7 to 15-9; "16-month-olds" ($N = 10$), mean

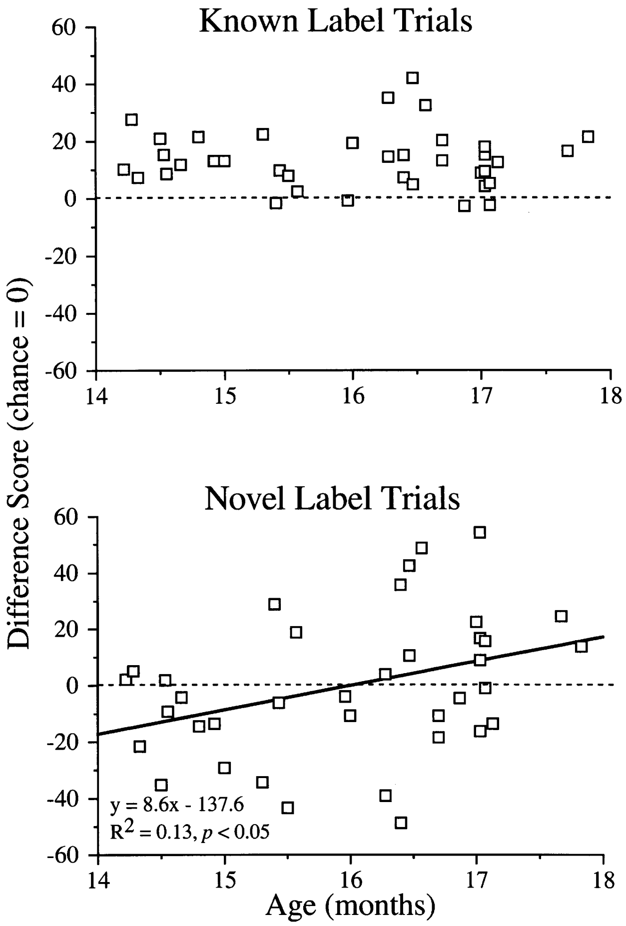

Fig. 1. Difference scores on Known (cup, ball, car) and Novel (dax) Label trials for each subject, defined as percent change in looking to the labeled target compared to baseline preference.

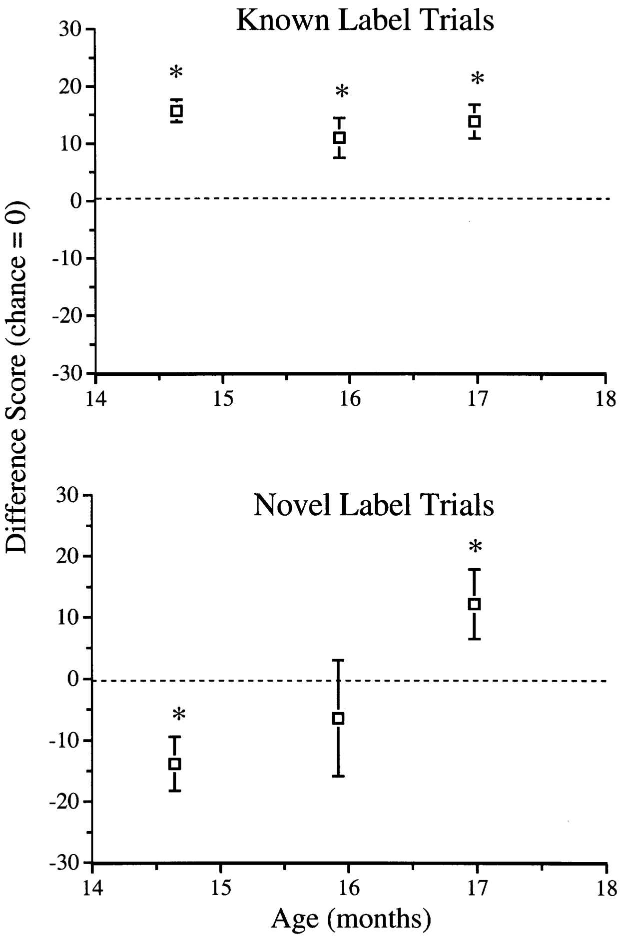

Fig. 2. Difference scores on Known (cup, ball, car) and Novel (dax) Label trials by age group, defined as percent change in looking to the labeled target compared to baseline preference (±SE).

15 months, 29 days; range 15-12 to 16-12; and "17-month-olds" ($N = 16$), mean 16 months, 29 days; range 16-14 to 17-25.

The difference scores for each group on Known Label trials are displayed in Fig. 2. Each group was tested against the chance level. As seen in Fig. 2, positive difference scores indicate that all ages significantly increased looking to the labeled target (cup, ball, car) above baseline preference on Known Label trials: 14-month-olds, $t(10) = 7.94$, $P < 0.05$; 16-month-olds, $t(9) = 3.16$, $P < 0.05$; 17-month-olds, $t(15) = 4.67$, $P < 0.05$. Thus, all ages succeeded with known labels.

The difference scores for each group on Novel Label trials are also displayed in Fig. 2. The difference scores for each group were tested against the chance level. As seen in Fig. 2, 14-month-olds significantly *decreased* looking to the novel target (i.e. dax) compared to their baseline preference ($t(10) = -3.14$, $P < 0.05$). Sixteen-month-olds were not different from chance ($t(9) = -0.69$, $P = 0.51$). And, 17-month-olds significantly *increased* looking to the novel target (i.e. dax) compared to their baseline preference ($t(15) = 2.14$, $P < 0.05$). The success of 17-month-olds in mapping novel labels to novel objects is convergent evidence that 17 months is the onset of the mature word-learning strategy (Mervis & Bertrand, 1994).

The significantly negative difference scores of the 14-month-olds are surprising. Because difference scores were derived from subtracting percent-looking to the target before label onset from percent-looking to the target after label onset, negative difference scores indicate that 14-month-olds increased their looking to the *distractor* following label onset. That is, 14-month-olds significantly increased looking to the known object (i.e. car) in response to hearing the novel label "dax".

What might this mean? First it is important to note the robustness of this result. There is no indication that this pattern of looking developed during the course of the experimental session. Fourteen-month-olds showed this looking pattern on the very first Novel Label trial, significantly increasing looking to the known object (car) above baseline preference ($t(10) = -2.41$, $P < 0.05$).[2] Further, these infants showed no tendency to get better or worse on Novel Label trials throughout the experimental session as measured by a linear regression on difference scores with trial order as the independent variable ($t(1,46) = 1.07$, $P = 0.29$). And, because difference scores take baseline preferences into account, 14-month-olds' increased looking to the known object (car) cannot be described as a simple image preference to look at the car, or as a preference to look at objects for which the child knows a name (i.e. "car") (Schafer, Plunkett, & Harris, 1999). Lastly, frame-by-frame results indicated that this increase was monotonic for 14-month-olds. At no point during the 4 s comprehension measure did 14-month-olds increase looking to the novel object and, by trial's end, 14-month-olds were looking at the novel object on only 20% of all Novel Label trials.

3. Experiment 2

Beyond the above internal controls, there are several possible explanations for the 14-month-olds' negative difference scores on Novel Label trials ("dax"). Experiment 2 sought to control for all incidental aspects of the experiment which might have caused the 14-month-olds' surprising performance.

Although an overall preference for the known object (car) cannot explain why 14-month-olds significantly increased looking to the car above baseline preference in Experiment 1, perhaps these infants had a preference for the known object (car) that developed as a Novel Label trial unfolded. This would cause difference scores to be negative on Novel Label trials even if no label had been spoken. Another possibility is that, failing to understand the novel label, 14-month-olds preferred to look at the known object (car) in an attempt to comply with the directive to "Look at that [something]" (Schafer et al., 1999). Experiment 2 tests these hypotheses, and more generally, whether any factor other than the

[2] Also consistent with the overall pattern of results, 17-month-olds significantly increased looking to the novel object on the first Novel Label trial ($t(15) = 2.55$, $P < 0.05$).

presence of the novel label "dax" could account for the increased looking to the known object (car).

Eleven infants, age-matched to the 14-month-olds in Experiment 1 (mean age 14 months, 25 days; range 13-25 to 15-13), participated in a control study that was identical to Experiment 1, but with the object labels removed. Thus, during each trial, two objects appeared, simultaneously, one on each monitor (cup–ball, car–phototube). After a 3 s silent measure of baseline image preference, a neutral carrier phrase was played (e.g. "Look at that."). Following the offset of the carrier phrase, infants' looking to each screen was measured for 4 s, after which the object that should have been labeled (had this been Experiment 1) "danced" on the screen to music. Thus, all aspects of Experiments 1 and 2 were identical, with the exception of the presence or absence of the object labels. Therefore, if any incidental aspects of the trial or the labeling act were the source of the negative difference scores observed in Experiment 1, control subjects' scores should also be negative.

Experiment 2 confirmed that it was the novel label ("dax"), and not any other aspect of the trial or labeling act that drove 14-month-olds' negative difference scores in Experiment 1. Difference scores on Novel Label trials (or would-be Novel Label trials in the case of Experiment 2) were entered into a 2 (experiment condition) × 2 (sex) × 2 (trial order) ANOVA with age as a continuous covariant. There was a main effect of experiment condition ($F(1,14) = 4.69$, $P < 0.05$) and no other significant effects. The main effect of experiment condition was due to Experiment 1 subjects' difference scores being negative on Novel Label trials ("dax") while control subjects' scores were not different from chance ($t(10) = -0.10$, $P = 0.92$).[3] As seen in Fig. 3, control subjects did not significantly increase looking to the known object (car) following the carrier phrase.

Presented in Fig. 3 are the percent-looking times that were used to create Novel Label trial difference scores for each age group (Experiment 1) and controls (Experiment 2). Difference scores were computed by subtracting baseline preference-looking before label onset from comprehension-looking after label onset. The four groups (controls, 14-month-olds, 16-month-olds, and 17-month-olds) did not differ in their baseline preferences to look at the novel object (dax) ($F(3,44) = 0.60$, $P = 0.98$). As seen in Fig. 3, all significant differences between the groups were due to differences in comprehension-looking after label onset (or carrier phrase offset for the control group) ($F(3,44) = 3.48$, $P < 0.05$).

Given that the only difference between Experiments 1 and 2 was the presence or absence of the object labels, 14-month-old infants' increased looking to the known object (car) in Experiment 1 was due solely to the novel label ("dax"). This change in looking cannot be due to a baseline image preference, an image preference that developed during the trial, a preference to look at objects that have known names, or a change in image preference given a labeling context.

[3] A similar ANOVA was run on subjects' Known Label trial difference scores. There was a main effect of experiment condition ($F(1,14) = 11.16$, $P < 0.05$) and no other significant effects. Experiment 1 subjects' Known Label trial difference scores were highly positive while those of control subjects were not different from chance ($t(1,10) = -0.99$, $P = 0.35$).

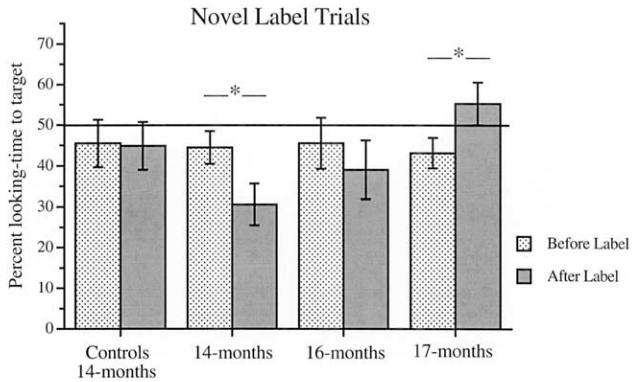

Fig. 3. Percent looking-time to the novel object (dax) before and after label onset is displayed for three age groups (Experiment 1), and percent looking-time before and after carrier phrase is displayed for control subjects (Experiment 2) (±SE). Difference scores were computed by subtracting looking before label from looking after label (or carrier phrase). Chance looking both before and after label is 50%.

4. Discussion

The present study demonstrates two theoretically important results. First, Experiment 1 shows the development of a word-learning strategy within a single paradigm. This work contributes to the debate on whether constraints in general help get word-learning off the ground. Experiment 1 presents evidence from a looking-time procedure that 17 months is the age of onset of the strategy studied here. This converges with findings from a pointing procedure (Mervis & Bertrand, 1994). These results argue that children learn their first words without the aid of such a strategy.

Second, the developmental trajectory discovered here was not a simple one, from lacking a constraint to having one. If infants developed from simply lacking constraints to having them we would expect performance to develop from chance to gradual success. While it remains possible that the 14-month-olds in Experiment 1 are simply not invested in fixing the referent of the novel label, much can be gained from exploring this failure as a breakdown in the computations that underlie later success. The surprising form of the 14-month-olds' failure in the present study opens a door to characterizing those computations and the systematic way in which they may fail.

In an attempt to organize the debate concerning how word-learning constraints are implemented, I offer two computational proposals for how children map novel labels to novel objects in situations of referential ambiguity, as were tested here. First, Mutual Exclusivity (Markman, 1990, p. 165), a Pragmatic Account (Diesendruck & Markson, 2001), and Contrast (Clark, 1990) are all consistent with the proposal that children work through an implicit Disjunctive Syllogism, rejecting objects with known labels in the process of deducing the correct referent. The computational structure Disjunctive Syllogism is any argument of the form: A or B, not A, therefore B. For ME, the syllogism would run as follows: the novel name "dax" refers either to the car or to the novel object. Via ME, the name "dax" cannot refer to the car, because the car already has a name (i.e. "car"), and every object has only one name. Thus, by process of elimination, the novel name "dax" must refer to the novel object. Such a computational structure may be implemented without the child having to be an explicit hypothesis-tester. A Pragmatic Account and Contrast would share this inferential structure and simply change the principle guiding the rejection of the known object (car) in the second step of the syllogism.

Adults and preschoolers who succeed on Novel Label trials show looking patterns that are consistent with Disjunctive Syllogism. These participants systematically fixate and reject known object distractors before correctly mapping novel labels to novel objects (Halberda, 2002). One possible interpretation of the failure at 14 months is that these infants are directing attention to the known object (car) in order to check it as a possible referent and simply running out of time (a possibility currently under investigation). It is also possible that, after having rejected the known object, infants are failing to complete the inference. If rejection of the known object (car) is the necessary second step in the Disjunctive Syllogism, then increased looking to the known object (car) would be the result of remaining focused on this step (Halberda, 2002).

The second proposal for the successful mapping of novel labels to novel objects is that children may simply "map novelty to novelty". This structure is proposed by authors who have offered the Novel-Name Nameless-Category principle (N3C) (Golinkoff et al., 1992; Mervis & Bertrand, 1994; Mervis et al., 1994), and it is consistent with some versions of Contrast (Clark, 1990). N3C does not predict a syllogistic structure. Instead, according to N3C, children are positively drawn to map novel labels to novel objects, with no need to explicitly reject known object distractors (Mervis & Bertrand, 1994). Such a computational structure would be captured by a competition network where all possible referents compete for the novel label ("dax"), and the most novel object wins (Merriman, 1999). What counts as novelty has not been specified by the proponents of N3C, but, whether novelty is cashed out in terms of perceptual or linguistic familiarity, such a computational process would not predict the pattern of failure seen here, increased looking to the known object (car). Failure to reach a decision in a competition network should be continued sampling of all possible referents (MacWhinney, 1987). Thus, the principle of "map novelty to novelty" predicts that 14-month-olds should continue to fixate both the novel and the known object, not that subjects should increase looking to the known object (car) above baseline preference.

However, a modified version of the competition model may be consistent with the pattern of failure seen here. It is possible that 14-month-olds are driven to fixate the known object (car) because of this familiar object's activation in response to any name. Such an account can be tested because it makes the prediction that if presented with a novel and a known object (phototube and car) and told to "Look at the *ball*", 14-month-olds should again increase looking to the known object (car).

The developmental trajectory discovered here was not a simple one, from lacking a constraint to having one. Fourteen-month-olds are not simply failing to utilize a word-learning strategy. They are systematically and monotonically increasing looking to a known object (car) in response to hearing a novel label ("dax"). As has been the case with systematic but wrong responses by young children in Theory of Mind tasks (Perner, Leekam, & Wimmer, 1987) and Spatial Reasoning tasks (Hermer & Spelke, 1994, 1996), this surprising failure may open a door to understanding the computations that underlie later success. By looking ever younger, developmental psychologists attempt to discover where competence is first forming, with the goal of gaining insight into the mature structure. It is where competence falls apart in a systematic way that we may see the components which underlie a representational capacity.

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References

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: evidence for continuous mapping models. *Journal of Memory and Language*, *38*, 419–439.

Arriaga, R. I., Xu, F., & Carey, S. (1996). *A pragmatically natural assessment of early noun comprehension*. Poster presented at the 10th International Conference on Infant Studies, Providence, RI.

Carey, S. (1978). The child as word learner. In M. Halle, J. Bresnan & G. A. Miller (Eds.), *Linguistic theory and psychological reality*. Cambridge, MA: MIT Press.

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language*, *17*, 417–443.

Clark, E. V. (1993). *The lexicon in acquisition* (pp. 71–83). New York: Cambridge University Press.

Diesendruck, G., & Markson, L. (2001). Children's avoidance of lexical overlap: a pragmatic account. *Developmental Psychology*, *37* (5), 630–641.

Fernald, A., Pinto, J. P., Swingley, D., Weinberg, A., & McRoberts, G. W. (1998). Rapid gains in speed of verbal processing by infants in the 2nd year. *Psychological Science*, *9* (3), 72–75.

Gathercole, V.C. (1989). Contrast: a semantic constraint? *Journal of Child Language*, *16*, 685–702.

Golinkoff, R. M., Hirsh-Pasek, K., Bailey, L. M., & Wenger, N. R. (1992). Young children and adults use lexical principles to learn new nouns. *Journal of Developmental Psychology*, *28* (1), 99–108.

Golinkoff, R. M., Mervis, C. B., & Hirsh-Pasek, K. (1994). Early object labels: the case for a developmental lexical principles framework. *Journal of Child Language*, *21*, 125–155.

Halberda, J. (2002). Is this a dax I see before me? A computational analysis of mutual exclusivity, in preparation.

Hermer, L., & Spelke, L. (1994). A geometric process for spatial reorientation in young children. *Nature*, *370*, 57–59.

Hermer, L., & Spelke, L. (1996). Modularity and development: the case of spatial reorientation. *Cognition*, *61*, 195–232.

Hirsh-Pasek, K., & Golinkoff, R. (1996). The intermodal preferential looking paradigm reveals emergent language comprehension. In D. McDaniel, C. McKee & H. Cairns (Eds.), *Methods for assessing children's syntax*. Cambridge, MA: MIT Press.

MacWhinney, B. (1987). The competition model. In B. MacWhinney (Ed.), *Mechanisms of language acquisition* (pp. 249–308). Hillsdale, NJ: Lawrence Erlbaum Associates.

Markman, E. M. (1990). Constraints children place on word meanings. *Cognitive Science*, *14*, 154–173.

Markman, E. M. (1992). Constraints on word learning: speculations about their nature, origins and domain specificity. In M. R. Grunnar & M. P. Maratsos (Eds.), *Modularity and constraints in language and cognition: the Minnesota Symposium on Child Psychology* (pp. 59–101). Hillsdale, NJ: Erlbaum.

Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: taxonomic vs. thematic relations. *Cognitive Psychology*, *16*, 1–27.

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meaning of words. *Cognitive Psychology*, *20*, 121–157.

Merriman, W. E. (1999). Competition, attention, and young children's lexical processing. In B. MacWhinney (Ed.), *The emergence of language* (pp. 331–358). Mahwah, NJ: Lawrence Erlbaum Associates.

Merriman, W. E., & Bowman, L. L. (1989). Mutual exclusivity bias in children's word learning. *Monographs of the Society for Research in Child Development*, *54*(3–4, Serial No. 220).

Mervis, C. B. (1987). Child-basic object categories and early lexical development. In U. Neisser (Ed.), *Concepts and conceptual development: ecological and intellectual factors in categorization* (pp. 201–203). Cambridge: Cambridge University Press.

Mervis, C. B., & Bertrand, J. (1994). Acquisition of the novel name–nameless category (N3C) principle. *Child Development*, *65*, 1646–1662.

Mervis, C. B., Golinkoff, R. M., & Bertrand, J. (1994). Two-year-olds readily learn multiple labels for the same basic-level category. *Child Development*, *65*, 1163–1177.

Nelson, K. (1988). Constraints on learning? *Cognitive Development*, *3*, 221–246.

Object DataBank [Computer Software]. (1996). Providence, RI: TarrLab, Brown University.

Perner, J., Leekam, S., & Wimmer, H. (1987). Three-year-olds' difficulty with false belief: the case for a conceptual deficit. *British Journal of Developmental Psychology*, *5* (2), 125–137.

PsyScope [Computer Software]. (1994). Pittsburgh, PA: Carnegie Mellon University, Department of Psychology.

Sanderson, P. M. (1994). MacSHAPA (Version 1.02) [Computer Software]. Urbana, IL: University of Illinois at Urbana-Champaign.

Schafer, K., Plunkett, K., & Harris, P. (1999). What's in a name? Lexical knowledge drives infants' visual preferences in the absence of referential input. *Developmental Science*, *2*, 187–194.

Tomasello, M., & Barton, M. (1994). Learning words in non-ostensive contexts. *Developmental Psychology*, *30*, 639–650.